BIOLOGY

W·D·HENDERSON, M.A., B.Sc

THE·PEOPLE'S·BOOKS

THE
PEOPLE'S
BOOKS

BIOLOGY

BIOLOGY

BY W. D. HENDERSON
M.A. B.Sc., Ph.D., F.R.S.E.
ZOOLOGICAL LABORATORIES, THE UNIVERSITY, BRISTOL

LONDON: T. C. & E. C. JACK
67 LONG ACRE, W.C., AND EDINBURGH
NEW YORK: DODGE PUBLISHING CO.

PREFACE

In writing this Introduction to Biology, I have used, to a large extent, the notes of lectures delivered by my first teacher in Zoology, Professor J. Arthur Thomson. No doubt he will find many phrases and expressions and many lines of thought which are quite familiar; for using these I make no apology, for they seem to me to give the very essence of the subject briefly and very aptly. I must also express my debt to the writings of Professor Harvey Gibson, which I have found very helpful and illuminating.

It is quite possible that I may have omitted much that others would have put in, and that I have written more fully on some points which others would have curtailed; but be that as it may, I only hope that this Introduction will interest and be of some slight service to those who are beginning the study of Biology.

For all errors of fact and exposition I alone am responsible, and if I have interpreted any views or theories wrongly, I tender my sincere apologies.

W. D. H.

Bristol, 1913.

CONTENTS

INTRODUCTION

Many problems, for some of which no answer has as yet been found, arise in connection with the world of living things. How did they arise? How are they scattered over the face of the earth? What are they in themselves and in all their parts? How do they feed and grow and reproduce their kind? Why do they grow old and die? What is the secret of their activity and of its ability to change with the changes that occur in its surroundings?

These and many allied questions arise, and out of the attempts to answer such questions has arisen Biology or the Science of Life.

Biology may be defined, in the words of Professor J. Arthur Thomson, as "the science of the structure and activity, development and evolution of organisms, including man."

It cannot be pointed out too early that Biology does not concern itself with the particular kinds of plants and animals; that is the aim of the special sciences of Botany and Zoology, but it has to answer questions dealing with the form and structure of living things, with their activities, their origin, and the factors in their evolution.

The first of these questions—form and structure—so

simple on the surface, becomes more and more complex as we examine the plant or animal more carefully, using every means at our disposal, scalpel and microtome, stain and microscope. Thus this simple question leads up to the first of the sub-sections of Biology—Morphology.

In the second place Biology has to deal with the function of the plant or animal—what it does, how it does it, why it does it—or, in other words, Biology has to explain the "particular go" of the organism. The attempts to answer this have made another of the sub-sciences—Physiology.

Moreover, Biology has to inquire into the development not only of the individual, but of the race, and such inquiries have formed the allied sciences of Ontogeny and Phylogeny, or combining the two under one heading, Geneology.

And the last question it must try to answer is: how have those living creatures come to be as they are? What have been the intrinsic and extrinsic factors in their evolution? The grasping and wrestling with this in all its aspects has laid the foundations of the latest of the sub-sciences—Ætiology.

Biology, then, may be said to have four primary sub-sciences—Geneology, Morphology, Physiology, and Ætiology.

The aim of this little book is to give to the reader in language as free from technicalities as possible such a grasp of the main facts of Biology as may form a foundation for future reading.

BIOLOGY

CHAPTER I

THE ORIGIN OF LIFE

It is an indisputable fact that all the living organisms of which we have any cognisance at the present time arise from pre-existing organisms. As to the origin of life upon earth we know nothing. Various opinions have been expressed from the times of the early philosophers up to the present day. Leaving all the earlier beliefs as to the origin of life out of the question, we come to that which seems to be held by a very large number of scientific workers at the present time, namely, that living matter has been evolved from non-living matter on the earth's surface.

According to this view of the origin of life, all the criteria generally used in differentiating the living from the non-living are useless in so far as they are equally applicable to both. Movements which were thought to be characteristic of the lower organisms are found to be precisely reproduced by such substances as oil-drops and mercury globules. Even the taking in of food and its elaboration, the process of growth and such periodic functions as reproduction can no longer be considered a characteristic feature of living matter; for all these are

common alike to the living and the non-living. Leduc claims to have been able to reproduce all the features of so complex a process as Karyokinesis by purely inorganic substances, and the researches of Loeb seem to show that such a vital phenomenon as fertilisation is no longer necessary, for development can be brought about by purely chemico-physical means.

The chemical constitution of living matter, even that of the nucleus itself, all point towards the belief that the synthesis of living matter may soon be carried out.

Looking now at the evolution of living matter by the light which is shed upon it by the evolution of matter in general, there must have been a gradual process of change from material which was lifeless to material which has all the characteristics of what we call living matter. Now this gradually evolved material may have been in the form of minute ultramicroscopic particles, and so no traces of it are found in the geological record.

Many of the supporters of this view believe that evolution did so take place, but that there was only one period in the earth's existence at which this was possible, a period when conditions of heat and the solubility of substance were more favourable to the formation of complex substances than they are at the present time.

Let us briefly consider the steps in this evolution of living matter. The inorganic materials on the earth are constantly undergoing transition; new chemical combinations are being formed, old broken up, and it is during some of these changes that the first steps were taken towards the evolution of living matter. As living matter always requires water, the first step must

have been one in which some colloidal form was evolved; it may have been ultramicroscopic colloidal particles. Now all colloidal material has the tendency to divide when it has reached a certain size, and so this colloidal slime would have one of the properties of living matter. As the separated parts have the same properties as the parent the process would go on, growth would take place, and it would be followed by reproduction. From this point it is quite easy to imagine that there was the segregation of more highly phosphorised material which, in the course of generations, gradually assumed the form of a definite nucleus, and all the subsequent stages in the evolution would be quite simple.

We have stated the current belief as to the origin of life, and sketched briefly and roughly the stages in that evolution. Have we any evidence to justify the belief that living matter is being evolved at the present time as many believe? It entirely depends on what we mean by life and living matter. If we agree with Bastian and especially with Burke, then there are forms of living matter, so simple that we do not recognise them as such, constantly coming into being, passing out of existence and leaving no trace behind them, as the power of reproduction is possible only at a much later stage in their evolution.

With regard to this view of the origin of life, in our opinion it has failed to explain many of the features of living matter by purely physical and chemical laws. Yet we do not wish anyone to go away with the idea that this is impossible; all we mean is that up to the present they have failed to do so, and that even if in the course of a few generations they may show that living matter has

been evolved from "inorganic" substances, then we shall find that what we at present consider inorganic is in reality organic matter.

CHAPTER II

THE CRITERIA OF LIFE

If we lay aside all speculation as to the origin of Life, and consider the world around us, we are able to place most of the things we see under one of two categories, the living and the dead. The very fact that we group things under these headings makes it necessary for us to be clear as to what we mean by living and non-living, or, in other words, to lay down some criteria by which the living may be distinguished from the non-living. As a fairly satisfactory and quite workable set of criteria, we may take the three properties laid down by Huxley as distinctive, or peculiar to living matter.

1. Its chemical composition.

It is a protein practically unknown except as a product of living substance. No one as yet has been able to give its exact composition, as it is impossible to study it apart from other elements which may aid it only in carrying out certain of its functions. This much may be said that it is a highly complex combination of Oxygen, Hydrogen, Carbon, and Nitrogen, and is known as protoplasm.

2. Its universal disintegration and waste by oxidation, and its concomitant reintegration by intussusception.

All life is accompanied by the liberation of a certain amount of energy which implies the breaking up of the complex protoplasm by oxidation into simpler but more highly oxidised compounds. There is, therefore, a continual waste going on in living things, and this would ultimately lead to the total destruction of the protoplasm were there not within the living substance a power to make good this waste. This power to make good the continual waste is one of the most characteristic features of living substances, and is carried on by a process of intussusception; that is, the continual absorption of new material from without and its transformation into the substance of the body. So that we may say the living organism is a centre of continual waste and repair, of nicely balanced destructive and constructive processes.

3. Its tendency to undergo cyclical changes.

The cyclical changes are, for the most part, incidental to re-integration. The living organism coming into being as the result of previous living matter (for we have no evidence of non-living matter giving rise to living), proceeds to increase its own amount of living substance, and to dispose of the excess thus formed in setting it free as new individuals, or, in other words, in reproducing its kind. This power of reproducing its kind is a necessary feature of living organisms, for it is the heritage of all living organisms that a stage is reached when the constructive processes are no longer able to outweigh or even to balance the destructive processes, and what we call death ensues. But in spite of this ceasing to live, the original organism has been able to pass on its peculiar properties through its periodic or cyclical function of reproduction.

One cannot be too strongly warned against expecting that these criteria can be applied successfully at first, for there are certain stages in the life of the living organism when all the life processes seem not to exist. This passive state found alike in plants and animals may be considered as a state in which the living organism becomes capable of withstanding conditions unfavourable to activity. We find, for example, that seeds may lie dormant for a long period of years, and that some animals may lie in this dormant condition for periods up to fourteen years. There is nothing to distinguish the substance of the living organisms under these conditions from non-living substance, but still we find that when introduced into favourable conditions, they germinate or again begin an active life. This latency of life is well shown by seeds which have been found in the graves of mummies and also in the case of paste-eels. It seems certain that certain conditions such as cold, dryness or failure in the food-supply, tend to induce the passive state, while warmth, presence of moisture, and a suitable food-supply are factors in restoring the active state.

CHAPTER III

THE CELL

Every living organism consists of a single unit of living matter, a cell, or of an aggregate of these units arranged in many and diverse ways. At first it was supposed that every unit exhibited more or less uniformity of

structure, but it is now a matter of common knowledge that this is not the case. There is such a dissimilarity that it is practically impossible to give a definition that will hold for all cells, but in this chapter by cell is meant a structure which is capable of displaying all the vital manifestations, but not capable of being divided into simpler vital units.

In regard to size, cells vary enormously. Many of the bacteria are so small as to be visible only with the highest powers of the microscope, while other cells are quite visible to the naked eye, and may even reach, in the case of yolk-laden eggs, some inches in size. Size therefore is unimportant.

In regard to structure, cells vary as much as they do in size. Some cells may be a mere microscopic speck in which no structure can be made out, others may have a definite structure and contain numerous clearly-defined parts. But as there are many cells in which no one, up to the present time, has been able to identify those well-known parts, we may take it that the essential living substance is the protoplasm or cytoplasm. Numerous attempts have been made to find a definite structure in the cytoplasm; it has been said by some to be reticular, others say it is fibrillar, while others maintain that it is granular. The truth probably lies in all three of these views, as it is quite possible that at one time it may be reticular, at another fibrillar, and at yet another granular.

We may therefore say that the cytoplasm is a substance with no definite structure, in which we find a large number of granules. These granules are probably of different nature and function, as they react differently

when treated with different staining substances. It is now supposed that these granules are the products of the living substance, and useful in its various activities. Which of these granules actually belong to the cytoplasm it is difficult to say, as we undoubtedly find many granules in certain cells, which may be looked upon as reserve foodstuff, and in others substances are found which are the products simply of the cellular activity, and are present at one time, absent at another.

In such cells as the protozoan amœba, paramœcium, and others, granules exist temporarily which may be the unutilised products of digestion.

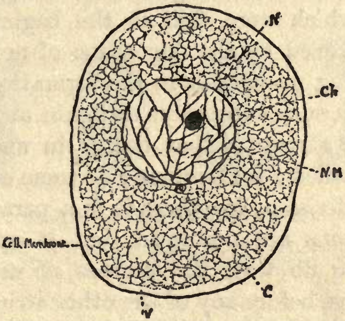
In the plant cells it is even more difficult to say which of the granules are essential and which are not. Certain granules in plants are without doubt not essential part of the cytoplasm at all, for example, the starch and aleurone grains, and numerous crystal-like bodies such as oxalates.

The second essential structure of the cell is the nucleus. It appears usually as a spheroidal mass in its more perfect form, the size of which bears a definite relation to the size of the cell. It is usually enclosed by a definite membrane-like outer coating, and consists of a fluid-like substance and also of a material that is more or less filamentous in appearance. By the use of various stains we are able to recognise that the nuclear substance is different from the cytoplasm chemically, and our knowledge of cell-structure has been largely increased by a study of the effects of the different staining reagents on the various parts of the cell.

Of the various substances found in a cell, the chief

nuclear substances are the chromatin and the linin, the former having a marked affinity for all nuclear stains, while the latter remains unaffected. These chromatin-bodies are explained more fully in the chapter on cell-division.

The majority of cells contain a single nucleus, some of the protozoa are supplied with two, while other forms apparently contain a large number of nuclei lying in an



N, the Nucleolus; *Ch*, chromatin network; *NM*, nuclear membrane; *C*, the centrosome; *V*, vacuole.

undifferentiated mass of protoplasm. These latter are, however, in many cases not a single cell in the usual sense, but a body formed by the coalescence of a number of cells.

The shape of the nucleus may vary exceedingly. It may be spherical, ovoid, branched, horse-shoe shaped, reticular or even moniliform.

The cell wall also is subject to considerable variation. In most of the lowest forms of life there is none, and this is also true of the greater number of cells in the metazoa. From this stage, with no cell wall but only a slightly

more dense arrangement in the protoplasm, we pass to forms where there is a very delicate cuticle or pellicle, as in paramœcium, and finally to such cells as the encysted stages of many of the lower forms, and the spores of bacteria where the cyst or cell wall has become a dense, highly resistant structure. The highest development of cell wall is seen in the higher plants, where it may be said to be a product of the cell rather than a part of the cell. In the growth of a higher plant the cell walls, which were thin at the beginning, become greatly thickened by the deposition of new layers, and this thickening may result in the formation of cellulose, and finally in such substances as lignin and suberin.

One other structure that occurs in many cells is a small body called a centrosome ; in some cells it appears just before division, in others it is a permanency. Its exact functions are unknown, but it apparently has something to do with the process of division, for it divides always before any of the other structures divide.

There are, in many cells, structures called vacuoles. In vegetable cells they are probably drops of sap which distend the cell during nutrition. In animal cells the vacuoles seem to be different, and are often formed in definite places. There they may help in the circulation of the digested food material and so assist assimilation, or they may act to a certain extent as organs for the excretion of waste nitrogenous matter.

These cell-vacuoles are in many cases simply stores of reserve material, and this is well illustrated by the globules of fat and glycogen found in the liver cells of man.

CHAPTER IV

CELL-DIVISION

THE process of cell-division is one of fundamental importance, since it is the general mode of organic growth. For a certain time the cells in any organism continue to grow, but the cell's increase is restricted within

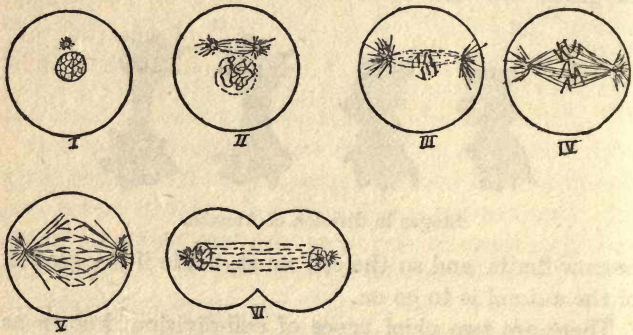
Stages in division of Amœba.

narrow limits, and so the cell must divide if the growth of the animal is to go on.

There are two chief types of cell-division, known as the direct and indirect, or as the amitotic and mitotic or karyokinetic. The former is the less complex, and is usually marked by the dumb-bell-like constriction of the nucleus; and without complex preliminaries one cell divides into two. In the mitotic or karyokinetic, which seems to be usual, there is a whole complex series of changes, the ultimate end of which is to divide every part of the chromatin of the mother-cells equally between the daughter-cells.

We must content ourselves with a very brief account of this karyokinesis. In a cell with a resting nucleus, it will be found that the nuclear membrane is quite

distinct, and that the chromatin of the nucleus is in the form of a network of irregularly-disposed threads. But when the cell prepares for division, the chromatin assumes the form of a continuous coiled thread—the spireme—or it breaks up into a definite number of fragments which are either straight or loop-shaped. These fragments or loops gradually give rise to the chromosomes, and during this stage the nuclear membrane



Stages in Karyokinesis.

disappears. Meanwhile the centrosome divides into two, and the two parts take up their positions at opposite poles. Between the two centrosomes a number of delicate fibres stretch, forming what is called a spindle, and radiating out from each centrosome are numerous fibres which stretch into the protoplasm. The chromosomes are then arranged in an equatorial plate at the centre of the spindle fibres. Then each chromosome splits lengthways into two similar portions, forming a double set, which are pulled, pushed, or otherwise travel along the spindle fibres towards the centrosomes. When

each group has nearly reached the centrosome, the whole cell divides into two, each of which has a centrosome and half the chromatin of its parent. The chromosomes of the new cells either break up or unite, and in every case form a fresh network or a new spireme. The spindle fibres disappear and the karyokinetic cycle begins again.

This is the simplest form of karyokinesis. Many complications occur in the formation of the reproductive cells. In plants, again, there may be no centrosome present. The whole question is full of uncertainties, and the actual forces that bring about these complicated changes are little understood.

CHAPTER V

DIFFERENTIATION OF STRUCTURE AND DIVISION OF LABOUR

A CURSORY glance at living organisms shows that we can arrange plants and animals in two series, in each of which there is a gradual transition from simple to more complex forms. This does not mean that we are able to connect each step in this series by an infinite number of fine gradations, but that on the whole there is a gradual increase in complexity as we advance from what are called the lower to what we call the higher forms of either plant or animal life. What the exact benefits of this increase in complexity are, it is exceedingly difficult to say, as we find extremely simple forms living and thriving and holding their own side by side with the more highly complex forms.

The simplest forms of living things are single-celled, and in these single cells all the daily and periodic functions, such as digestion, growth, response to stimuli, excretion, and reproduction occur, and are carried on just as efficiently as in the more highly complex, and that, too, without any special organs for carrying out these functions.

From these single-celled forms we pass to others where we have the first trace of differentiation, the outer layer of the body developed into a special layer or wall. In such forms we may have special organs of locomotion developed either as hair-like or whip-like outgrowths. We find also that certain spots on the cell are set apart for special purposes, for whereas in amœba the food could enter at any point, in paramœcium it can enter at one spot only. A skeleton begins to make its appearance and reaches a high degree of complexity in such forms as the Radiolaria, Foraminifera, and Diatoms.

We pass from these single-celled forms to a stage where we have a large number of similar forms living together in a group, yet preserving their individual identity. This is seen, for example, in Microgromia, in Epistylis, in Carchesium, and in Spirogyra, but it must be remembered that from these groups any member may break away and start an independent life. A further complication ensues in such forms as Volvox, where the cells are incapable of breaking away; that is, they are mutually dependent on one another; and this is still further complicated by the fact that this mutual dependence has, as a result, the setting aside of certain of the cells of the group for special duties. In Volvox

certain of the cells are set aside for reproduction and others for supplying food.

It is just possible that from some such group of cells as Volvox, nature passed from the simple uni-cellular form, where each cell was practically as good as its neighbour, to the multi-cellular stage, where each cell or set of cells was wholly dependent for its well-being on the close connection with other cells. It is easy to imagine how this may have come about, and the formation of a body or soma been reached.

In the lowest forms of multi-cellular organisms, we find already a definite distribution of the work that must be performed for the good of the organism as a whole. Certain cells are formed into an outer or protective layer, and others into an inner layer, the main function of which is nutritive, and the simpler sponges supply beautiful examples of this. The structure of these simple forms becomes still more complicated, for example in Hydra, where we find that special cells in the outer layer are set aside for such purposes as defence, or it may be for locomotion, or even for the transmission of stimuli. Moreover in Hydra, and even in the sponges, there is a gradual development of an amorphous layer between the outer and the inner layers, and the gradual development of this means that the other cells are being placed usually in a position less suitable for carrying on the duties detailed to them.

The increasing complexity of structure is apparently a matter of necessity. As specialisation increases, means must be taken to insure that the various types of cells receive a suitable supply of nourishment, and so the organs of locomotion and of digestion develop; and as

the specialisation becomes more marked, there must be some means of communication between the various cells, and this may arise in a special modification of some or all of the muscle-cells as a primitive type of nervous system.

Further, as the muscular system increases, a skeleton becomes necessary, if for nothing else, at least as a framework for the attachment of the muscles.

A better idea of the gradual increase in complexity, and consequently in the gradual differentiation of cells and the division of labour between the cells, may be gained if we trace the development of a few of the more important systems.

All uni-cellular organisms nourish themselves without any special organ being set aside for the preparation of the food. In amœba the food is digested anywhere, and the nutritive substances are distributed throughout the protoplasm, but in paramœcium the food particles have a definite tract of circulation, and all follow it, so that we may say there is a hint here of an alimentary canal. In the colonial forms, such as Spirogyra or Epistylis, there is nothing to suggest that any individual contributes to the support of any other, but it is just possible that this may occur in forms such as Microgromia, as it certainly does in the case of Volvox. Among the majority of plants a common interest with regard to nutrition is soon established, and persists even among the higher forms of plant life.

In animals, on the other hand, we find that among the lowest forms of multi-cellular organisms there is a distinct set of cells set aside for nutritive purposes. The layer of cells surrounding the central cavity in Hydra produce some digestive ferment which acts on

the food that enters this gastral or central cavity, and the products of the digestion are absorbed by the cells and distributed to all the cells of the body. As we ascend the scale we find that this inner layer becomes more and more specialised for this purpose, until we find in the worms that the inner layer is nothing more or less than an enzyme-producing layer, that is, a layer specialised for digestive purposes. Further, this central layer had in such forms as Hydra, a common opening for the entrance of the food particles and the outlet of the undigested remains, but as the enzyme specialisation increased, a second opening, usually at the extreme opposite end, was developed for the outlet of the undigested remains of the food, so that we have now reached a stage, in the worm, for instance, where there is a special tube in the body for the purpose of digesting and dealing with the food.

Once this tube has been acquired it does not disappear again. It persists and continues to increase in complexity. The anterior end or mouth now becomes specialised for the purpose of breaking up the food substances, and ultimately it develops such structures as teeth for crushing the food. Differentiation continues, and we find certain portions of the alimentary tube set aside for special duties. A portion is set aside for the carrying out of the digestive processes, and still another for the absorption of the products of digestion. Again, certain parts are set aside for supplying certain of the digestive ferments, and this gradually leads to the formation of special glands. The final result of this is the highly complex alimentary canal we find in man and in the higher vertebrates.

An alimentary canal is of little use unless it be put into a position to obtain material to work upon. In plants the food-materials are everywhere present, water, inorganic salts, and gases from the air, but the food of animals can be obtained only as the results of the work of previous living organisms. It is not to be found, therefore, in every place, and so the food must be brought to the animal or the animal must be supplied with organs to take it to the food, that is, organs of locomotion must be developed.

The uni-cellular forms of organisms seem to possess a generalised locomotory power which manifests itself in the pushing out of processes called pseudopodia and the movement of the cell after these. The next step is the development of hair-like or whip-like outgrowths of the outer layer, which set up currents that carry the food to the body in sedentary forms such as Vorticella, or, in the case of free organisms, such as Paramœcium, propel them through the medium in which they live, and so enable them to obtain the necessary supply of food.

This specialisation continues, and in Cœlenterates we find that cells are set aside which by their power of contraction are capable of causing the animal to move from place to place. There is a rapid development of these contractile or muscle cells, and the final result is the complex series of muscles found in higher animals.

True organs of locomotion in connection with these muscles make their appearance first in the bristles or setæ found in the segments of the earthworm. From these simple bristles we advance to such forms as the jointed limbs of insects and crabs, all the joints of which

are controlled by muscles. This leads naturally to the appendages of the vertebrates, which appear in a variety of forms—wings, legs, arms, and flappers.

Food must be distributed to all parts of the organism. This is done in the uni-cellular forms by the food entering the cell and being digested there, but as soon as a body is formed this is impossible. Among the lower forms of plants and animals this is achieved by a passing of food from cell to cell, but this is not sufficient for the more complex forms. Plants provide themselves with vascular bundles by means of which there is a continuous circulation of food materials. The next step among animals is the formation of canal-like spaces in the body, usually merely outgrowths of the digestive cavity, which distribute the digestive food materials. Next we come to the formation of a series of vessels which are at first closely associated with the alimentary canal, and in these vessels there is a constant circulation, at first as it were undecided as to course, but ultimately taking up a definite direction of flow. The next step is the acquisition by some portion of these vessels of a power of contraction and expansion, and this portion takes upon itself the control of the propulsion which was at first caused by the muscular contractions of the body. Then comes the development of minute branches of these vessels, the capillaries.

As the complexity increases there is a demand made on the organism not only for a greater supply of this material, but also for a more efficient type of material. This means that the fluid, which in the lower forms differs only from the ordinary fluid in which the animal lives in containing more food material, must alter, which

it does by acquiring amœboid cells which we call the white blood corpuscles. This fluid or blood becomes more dense, and consequently its oxygen-affinity increases. This difference continues to increase until we find a second type of corpuscles evolved, the red; and the proportion of red to white increases, along with the development of organs which are adapted to increase the supply of oxygen required by this fluid to do its work.

Simultaneously with the development of these oxygen-supplying organs, whether they be gills as in fishes or lungs as in other forms, we find a gradually increasing complexity of the vessels that carry this fluid. The heart becomes more complex, increasing from the enlarged tube of the lower forms to a two-chambered structure as in fishes, and finally to the four-chambered heart of mammals and birds. At the same time there is an increasing development of the vessels themselves, and also a marked increase in their differentiation, some being set aside for carrying blood from the heart to the various parts of the soma, others for taking blood from these parts directly or indirectly back to the heart.

Vital activity being largely, if not wholly, a chemical process, it must be accompanied by the formation of waste products due to the activity of the living substance. These products are usually of no more use to the animal, and so must be got rid of. In the simpler forms they are thrown out to the exterior, and so the process of excretion, or getting rid of waste, is started. In a large number of the lower forms there are no special organs for this work, and it is in the worms that we find the first traces of such excretory organs. There waste may

escape directly through an opening in the body wall, but this stage is soon passed, and we find special tubes formed which arise singly and are not connected with one another. The earthworm, for instance, has a separate pair of these tubes, opening directly to the exterior, for practically every segment or ring in its body. For a considerable time in the animal kingdom there was no great advance on this, but among the vertebrates the tubules were restricted to certain parts of the body, and were grouped together into definite groups, and also came into direct communication with the blood or circulatory system. At the same time the tubules, instead of continuing to open directly to the exterior, opened into a common duct, which became the only means of communication with the exterior. The ultimate result of this was the development of the kidney or excretory organ as we find it in mammals. A hint of this union of ducts may be said to be seen in one of the worms, *Lanice conchilega*.

In a similar way we might trace the gradual increase in complexity in the reproductive and respiratory systems, but it will be more interesting to devote our attention for a short time to the nervous system.

As structural specialisation increases, some means must be taken to place the inner cells in communication with the outer, as it is important that the whole body of cells must work together. From the forms where there is a general irritability and power of response, we pass gradually upwards to such forms as Hydra and its allies, where some of the cells are modified to transmit the impulses to their neighbours, and in this modification we have the laying down of the foundations of the

nervous system. From these, forms are reached in which there is a highly complex system of superficial threads which ramify throughout the body, with all of its parts equally important. But soon there is a specialisation of some tract or other, and all the rest may be said to be branches of it, and the worms afford an excellent example of this division into a main or central part and a subsidiary or peripheral portion. The next complication is the gradual assumption by some portion, usually the anterior, of this nervous system, of a higher complexity of structure and function, and we get the first hints of a brain.

When we consider this more carefully, it is probable that it is the increasing complexity of the peripheral portion that is the exciting cause of the formation of a brain, with all its complex arrangement, by means of which the stimuli received from the external world are received, duly recorded, and acted upon. It is difficult to explain exactly the complexity of the various functions of the brain without entering into minute details which would benefit us little; but this much may be said: that a complicated system of nerve strands must be acted upon before the simplest external or internal stimulus can be received and acted upon by the brain.

The mere development of a brain is not the end of it all. For as the higher forms are evolved, a finer series of organs are also formed, to each of which the duty of looking after some particular kind of stimulus is delegated. The eye, for instance, is set aside for the reception of light-stimuli, the ear for the vibration-stimuli, and so on. Now as each of these special organs gradually developed, there was a corresponding increase in brain-

complexity, and a similar setting aside of some part of the brain to attend to the stimuli received. This complexity was not reached all at once, and so the brain, as we know it in man, must have passed through a very long developmental history, constantly adding to its already complex mechanism, and demanding also a corresponding complexity in all the structures associated with it.

Enough has been said to show that in the plant and the animal world alike there has been a division of labour and consequently a differentiation of structure, of which we can trace some steps imperfectly, it is true, and with many gaps. Every step in this increasing complexity has been fraught with momentous results for the higher animals, including man.

CHAPTER VI

SENSITIVITY IN PLANTS AND ANIMALS

THE power of responding to stimuli from within or without is a universal and fundamental characteristic of all living organisms; and it forms the starting-point of all manifestations of life. The property by which the organism responds to stimulation is known as irritability.

The stimuli that form the exciting cause of the irritable reactions are, (1) intrinsic or regulating, and (2) extrinsic or modifying.

The inherited or regulating stimuli simply determine that the living organism or substance shall pass through

a definite life-cycle; that is, perform certain functions, remain true to its type, and give rise to new individuals by which it will be survived. Those of the second class simply accelerate, retard, or modify the effects of the first type, or they may act as the finger on the trigger; that is, they may initiate the first set.

If we glance quite briefly at a few of the chief types of external stimuli, they will be found to be: (1) mechanical, *i.e.* when the organism is actually touched by some external agent; (2) chemical, where the stimulus is due not to the material itself but to some of its chemical properties; (3) thermal, where the stimulus is some variation in the temperature; (4) electric, where the stimulus is the influence of an electric current or shock; and (5) photic, the access of light or its absence.

The reactions occasioned by these external stimuli are known as tropisms, and we have such words as Heliotropism, the response to light; Chemotropism, the response to chemical stimulation; Thigmotropism, the response to mechanical stimulation; and many others.

Now every vital process varies in its activity within certain limits according to the duration, intensity, and quality of the stimulus, and the processes go on most satisfactorily when the stimuli are of a definite intensity, so that we have for every living organism an optimum intensity at which the best response is obtained, a minimum below which no response is obtained, and a maximum at which all response ceases.

Another point which must not be forgotten is that very rarely indeed does a stimulus act alone; it is usually accompanied by one or more other stimuli, which may

either increase or diminish the intensity of the original stimulus.

Occasionally also the effect produced is apparently out of all proportion to the stimulus, as for example the closing of the leaves in a Mimosa or sensitive plant when a few pinnules are touched. When we examine the conditions among living things in which such disproportionate results are obtained, we find that we have to deal with a complicated mechanism by which the stimulus is transmitted from cell to cell, and the result is the sum of many separate stimulations.

The application of a stimulus of any kind is followed by a quiescent period during which no visible response is given, but in which preparations, chemical or physical, or of some sort, are however taking place for the ultimate response.

The sensitive material in any living organism is protoplasm, and as there is a great variety of types of protoplasm, we must expect a very varied set of reactions to stimulation, and this is borne out by daily experience.

All plants and animals are alike sensitive to stimuli, although the response in animals is more marked and more rapid. A few illustrations of the sensitivity of plants and animals will make this clear.

If we take a young seedling of suitable size and place it horizontally on damp sawdust, we shall find, on examining it later, that the root has bent downwards towards the moisture and the shoot has bent upwards away from it. Both root and shoot were equally exposed to the influence of gravity, but a different response has been given by the two, so that we may lay it down as a general truth, that the same stimulus may produce

very different reactions in different kinds of protoplasm.

Some of the slime fungi in the early stages of their life always avoid the light and seek out the shade, while later on in life they seek out the light, illustrating the fact "that the same stimulus may induce different reactions in the same protoplasm at different stages in its life."

We may lay down a third general rule, which can be illustrated equally well in plants and animals, namely, that the varying intensities of the same stimulus produce different effects in the same protoplasm.

We have seen that the response to stimuli in animals is more rapid and more marked. This is due to the presence, in addition to a general sensitivity, of special sense organs; that is, tissues or parts of tissues that have become differentiated both in structure and in function for the sole purpose of receiving special classes of stimuli. Thus we have the eye for the appreciation of light and shade, the ear for sound, and special organs for taste, touch, and smell.

Why is it that the plant world is practically devoid of such organs? Self-preservation, and through that the preservation of the species, is of vital importance to every living organism. It must obtain the necessary quantity of suitable food; it must satisfy all its needs with regard to air and water; and it must have a suitable amount of heat if it is to live its life in a healthy manner. The difference is due to the different mode of life; the animal is active while the plant is sedentary; the food of the plant is abundant everywhere, while the animal can live only on organic food which is,

practically speaking, scarce, and must be sought for; and, lastly, this seeking for food involves dangers which must be avoided, dangers which do not exist for the plant.

That this latter feature, the activity of animals in seeking food, necessitated those special organs, is borne out by the fact that in such animals as lead a sedentary life, especially in those whose food supply is abundant, there is almost a total absence of specialised sense-organs.

CHAPTER VII

RESPONSE TO CERTAIN STIMULI IN PLANTS AND ANIMALS

LET us examine a little more closely the responses to various stimuli, *e.g.* gravity, light, touch, chemical substances, and the electric current.

Geotropism, or the response to the force of gravity, seems to be more clearly manifested among plants than among animals. Among the lower forms of plants and animals the response seems to be either very vague or undetermined, but among the higher forms of plant life the response is a general tendency to maintain a line of growth at right angles to the earth's surface, and this, too, irrespective of the source of heat or light.

Knight found that if germinating seeds were fastened on to a wheel rapidly revolving in a vertical direction, by means of which the force of gravity was overcome, the direction of growth obeyed the laws of centrifugal force, and the shoots grew towards the centre of the wheel, and the roots away. If the wheel was stopped

for a time, the roots gradually bent downwards towards the earth and the shoots upwards away from it. This is, the roots were positively geotropic, the shoots negatively so.

Another experiment which can be carried out without much trouble and gives excellent results, is as follows: Moisten some mustard-seeds and throw them against the inside of a damp, empty flower-pot, where they will adhere and germinate. The pot is then turned upside down over some damp sawdust and covered with a wet cloth. If the pot be examined after a few days, it will be seen that the roots have turned downwards, adhering to the sides of the pot, while the shoots have grown upwards but not in contact with the sides of the pot. Now place the pot in its normal position, cover it over with a dark cloth and leave it for a couple of days; the roots and shoots will then be seen to have curved round through an angle of 180 degrees and to have regained the original position, shoots upwards, roots downwards.

Among animals geotropic reactions are not so easily distinguished. Among the plant-like forms of the Cœlenterates numerous cases of marked geotropism are recorded. Loeb has found that some of the Holothurians are also negatively geotropic. But while definite positions with relation to gravity are assumed by all the higher forms, the mechanism connected therewith is so complex that it is impossible to say in how far they are geotropic.

Heliotropism, or the response to photic stimulation, is common among animals and plants alike. Everyone who has attempted to keep pot plants in a window knows how the shoots and leaves grow towards the window, thus necessitating constant turning if the

plants are to grow symmetrically. This is due to certain movements of the stem and the leaf-stalks, and these movements are called heliotropic.

Certain plants, such as the Mimosa, close the leaves at sunset and open them again only at sunrise. Such also is the case with a large number of flowers which close their petals at night, and open them again only when the sunlight strikes them in the morning. These heliotropic movements are especially important for the higher plants, as they bring the essential parts of the plant into the proper position with regard to the light, and thus make the normal healthy life of the plant possible.

In animals evidence of heliotropism is seen in the greater general activity during the day. Among the lower forms of animals heliotropic movements almost identical with those exhibited by plants are shown in a number of cases such as the worm Spirographis spallanzani. The most striking example of light-irritability among animals is seen in the specialised organs of vision, where cells are formed for collecting and intensifying the light.

It must be remembered that there are numerous examples among living organisms of avoidance of light; these are cases of what is called negative heliotropism, and one of the best examples is the root of any of the higher plants.

For sufficient illustration of the effect of sunlight on the human skin, we need only allude to sunburn and to freckles, which are simply small collections of pigment due to the action of the sunlight on the skin.

That chemotropism plays an important rôle in the life of plants and of animals goes without saying, and

it is practically certain that it is by chemotropism alone that specific integrity is maintained among plants and animals. By this we mean that fertilisation is made possible by the similarity of the chemotropism within the species, and that hybridisation is made difficult, if not impossible, between dissimilar species, owing to the difference in their chemotropism.

The readiness with which lower organisms such as an Amœba or Spirillum respond to the stimulating effect of food; the fact that caterpillars hatched out on the trunk of a tree creep up and reach the leaves upon which they feed, show that chemotropism is important.

The reaction of plants and of animals to water, a response which may be observed in nearly all forms of life, is a variety of chemotropism. That it is important can be easily shown and very neatly in the following way: Remove the bottom from any small box and replace it with fine meshed wire-netting, fill the box with wet bog-moss, and plant some peas or beans in it. Suspend the box, and in a few days it will be seen that the roots have in response to gravity grown down through the wire-netting. In a short time, however, the roots will bend upwards and re-enter the moss, as there is more moisture there than in the air, thus showing that under certain circumstances the hydrotropic stimulus is more powerful than the geotropic stimulus.

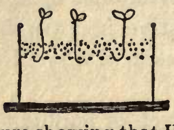


Figure showing that Hydrotropism is stronger than Geotropism.

Another form of chemotropism, namely the response to the effects of oxygen or oxytropism, is exhibited by all living organisms. To high and low forms alike

oxygen in some form is necessary, and to most the free oxygen of the air is sufficient. Some forms, however, cannot use this, and so they must obtain the oxygen they require by the analysis of compounds containing it.

Free oxygen seems to have a stupefying effect on anaerobic bacteria, and they lie dormant until all the free oxygen has been excluded; on the other hand, aerobic bacteria, if the oxygen supply be deficient, usually associate themselves with diatoms in order to profit by the oxygen thrown off by the diatoms.

All living organisms respond to electrical stimuli, or exhibit galvanotropism. An electric current, if too violent, causes the death of the animal or plant subjected to it, but if it be of mild intensity it may cause the organisms to cease all motion, or they may try to swim away from or to the positive pole. What the exact effect on the living organism is, is not known for certain, but one thing seems to be pretty sure, that a current of fairly high potential is injurious to animal life, whereas it seems to have a beneficial effect on plants when discharged in the air in their vicinity.

We have seen that plants as well as animals respond to stimuli. The chief difference between the plants and the animals is that in the plant the sensitiveness is more or less diffuse; in the animal the perception of the stimulus is localised, and there are centres to which these stimuli are transmitted. The animal analyses the stimulus there, and the reaction is caused by a stimulus generated at this centre. In the simplest case the cell that receives the stimulus also reacts, but in most multi-cellular forms the receiving and reacting elements are distinct. In the higher types of animal life this is

complicated by the addition of other elements, and also by the fact that the response may be a conscious or an unconscious one.

CHAPTER VIII

MOTION AND LOCOMOTION

WHILE it is quite true that every living organism exhibits some form of motion, this does not imply that it is visible to the naked eye. What is generally spoken of as motion, that is, the movement from place to place, is really locomotion, and as such must not be confused with the former.

Most animals are capable of moving from place to place; that is, they have the power of locomotion, and this is necessary to their existence, for their food is only local in distribution. Certain types, such as the zoophytes, barnacles, &c., are fixed and more plant-like, but all such forms live in a medium, the sea, where food is more evenly distributed and constantly circulated by the currents therein. On the other hand, the great majority of plants are fixed, but as their food is found practically everywhere, that is no disadvantage, and such locomotion as is found in the higher plants is, as a rule, purely physical and dependent on the absorption or evaporation of water. Moreover, locomotion in the higher plants and also in such of the lower forms as exhibit it, is not associated with the quest for food, but usually with the dispersal of the offspring.

The protoplasm within every cell, if that cell be

living, is in constant motion, and it consists in a regular movement of the cytoplasm within the limits of the cell; and it is possible that it subserves two purposes, namely, of bringing every portion of the cytoplasm into contact with the food, and of enabling all the food to be acted upon by the enzymes contained in the cell. This type of movement is seen to special advantage in plant cells, such as the cells of Elodea and the hairs of Tradescantia.

A slight step in advance is seen in certain of the unicellular organisms, for example, amœba, where there is in addition to the circulation of the protoplasm a primitive type of locomotion which we call amœboid movement. This movement consists in a flowing of the protoplasm which may be compared to rolling, and causes distension of the cell outlines and results in a slow progress. This type of movement is not confined to amœba; it is found in the leucocytes of the blood and in gland cells, &c., and in the plant world we see it in the Slime Fungi, and in the reproductive cells of many Fungi and Algæ. In addition to this amœboid type of movement, two other types, ciliary and flagellar, are exhibited by numerous of the lower forms of both plants and animals. In the higher animals ciliary movement, which is due to the action of minute hair-like outgrowths, is seen in the cells lining many of the tubes in the body, and in the cells covering the gills of mussels; while flagellar movement, due to longer, more

Cell showing Circulation of Protoplasm.

whip-like outgrowths, is exhibited by the spermatozoa only.

It is only natural that the animal with its more active and more hazardous life should have a greater variety of, and more specialised forms of, locomotory organs. There are, to name a few types only—the limbs of mammals, the wings of birds, the jointed limbs of crabs and insects, the tube feet of the sea-urchin, and the enormous muscular foot of the molluscs.

This leads naturally to the question of the skeleton or hard parts of the organism.

What are the functions of the skeleton ? It is manifestly clear that it protects the soft parts. The skull, for example, protects the brain ; the shell of the turtle, the crab and the mussel, the hard outer-covering of the beetle, protects the whole body ; and similar functions are performed by the hair of mammals, the skin of the reptiles and of the rhinoceros. In plants in like manner cork and corky cuticles are protective in function, so also are thorns, spines, resin, &c. Another function of the skeleton is to give rigidity, well exhibited in the limbs, while their mobility is not interfered with, owing to the development of joints, but this rigidity is also seen in the venation of a leaf, where the arrangement of the veins which are skeletal structures keep the leaf from crumpling up and also from being destroyed, for example, by high winds.

In animals the skeleton also serves another purpose, in that it gives points of attachment for the muscles of the body, and thus enables the parts to move singly or in concert. In plants the skeleton combines still another function with those of protection and rigidity, namely,

that of circulating both crude and manufactured food-materials to all parts of the body.

What, then, is the nature of this skeleton? In animals there is an infinite variety of substances; it may consist, as in many of the lower forms, of a thin horn-like substance with or without an additional impregnation of various salts, while in the higher animals it consists mainly of cartilage and bone. In plants the skeleton consists mostly of wood.

A chemical examination shows that about two-thirds of the weight of the animal skeleton consists of mineral matter, while only about two to five per cent. of the wood consists of inorganic salts.

In structure there is also a great difference. Wood consists of overlapping spindle-shaped fibres, while bone is built up of concentric lamellæ, which are, as it were, firmly fixed together by projecting processes, which often penetrate into several of the other lamellæ.

Another point of great interest in connection with the skeleton is its disposition throughout the body. In plants where the chief strain to be withstood is the tearing caused when the trunk is bending before the wind, we find that the skeleton of the stem is near the outside, while the roots which have to bear a rectilineal strain and are seldom if ever subjected to bending, have the vascular and skeletal tissue aggregated in the centre. This difference in the disposition of the skeletal tissue is entirely in accordance with elementary physical laws.

On the other hand, the chief force to be contended with in animals is the crushing force, and on this account we have the skeleton arranged somewhat differently.

There is a greater frequency of the arch arrangement, in which the bones form the sides of the arch and the muscles act as the tie-beams. But many of the bones have also to withstand a tearing or bending force, and in such cases they are arranged more or less after the pattern of the hollow column; this is exactly on the same lines as the skeleton in the majority of plants.

CHAPTER IX

FOOD

If we inquire into the meaning of the continuous activity of living organisms, remembering all the time that every phase of activity is an expenditure of energy and results in oxidation and finally in molecular transformations, we find that it can be explained only through the self-sustaining power of the organism, and this self-sustaining power is the power of introducing new matter to replace what has been used up.

Such introduced matter constitutes the food of the organism, and so we may define food as any substance from which a living organism is able to derive material for its sustenance. This is food in its widest sense, and under this definition all the inorganic compounds could be safely included. But we must remember one fact too often glossed over, that no protoplasm, whether of plant or of animal, can assimilate such inorganic substances until they are united into the complex substances known as organic compounds. Now organic compounds are found in nature only as the products

of the activity of plants or of animals, or of their decomposition. This apparently leads to a deadlock which we shall try to explain later. Here we must try to find out how food properly so called can be a store of energy.

We must remember that every organism, if alive, is constantly doing work, whether this work be external and visible, or internal and invisible. For this work energy must be expended, and this naturally means that there is a source of energy. Now energy occurs in two states, potential and kinetic. By potential energy we mean that a body is capable of doing work, although at the time it is not so doing. Physicists tell us that energy may be recognised in several different forms—chemical energy, thermal energy, electrical energy, and so on, and by chemical energy they mean that form of energy that is exhibited when the necessary units or atoms combine to form a molecule. Thus in the formation of a molecule of carbon dioxide, in which there is one atom of carbon and two of oxygen, there is a linking up of the various atoms, and in this process energy is set free.

Again, we are told that the various forms of energy are reducible to one, and that each may be changed, and in Nature is constantly being changed, into another. Yet in spite of all these changes the sum total of all the energies in the Universe is a constant quantity. The best way to measure the amount of energy expended in a day by a living organism is to measure it in terms of heat, and when this is done we find that a considerable number of heat-units or calories has been expended. Now the only possible place where this energy can have been stored is in the food.

If we analyse the various organic compounds used as food, we shall see that there is a marked deficiency in oxygen, although all their constituent elements have a marked affinity for it. They are prevented from satisfying their affinity for oxygen by the combinations in which they are grouped. Now, if we make the conditions favourable for the satisfaction of their oxygen affinities new combinations are formed, and there is a new grouping of the atoms, and during this process heat is evolved and consequently energy is liberated. We see, therefore, that the organic compounds used by the organism as food are a store of potential energy, which is ready to be transformed into kinetic energy under certain conditions.

Every living organism is constantly taking in oxygen in the process of respiration, and this oxygen is carried to the various parts of the body which are doing work, and there it unites with the complex organic substances which are poor in oxygen and themselves ready to unite with it, and in the union kinetic energy is liberated.

We have seen that food can be the only store of the energy required by every organism for its daily life, and also that by the addition of oxygen this potential energy stored up in the food is transmuted to kinetic energy. There are various other ways by which this can be brought about, but there is no need to consider them here.

There are two other questions in relation to food that we must consider—first, how these organic compounds are so transformed that the protoplasm may make use of them, and, secondly, how these organic compounds are built up.

Food, if it is to be of any use to the organism, must be suited to its needs, and also in a state of solution. Now every transformation of food by a third body from an insoluble to a soluble and from an indiffusible to a diffusible condition, whatever the precise chemical change, is summed up in the term digestion. This process of digestion is the same in plant and animal; it affects the same kinds of substances, produces the same results, and is carried on by the same sorts of agents.

Let us now examine two prominent types of digestion —that of a higher mammal, say man, and that of one of the higher plants.

In animals the food, which is of three chief kinds, proteids, carbohydrates, and fats, is chewed or masticated in the mouth and mixed with the secretion of the salivary gland—an enzyme known as ptyalin, which acts upon the starchy matter and changes it into malt sugar. The mixed food is then transferred to the stomach, where further secretions from the glands in the stomach walls are poured into it. The chief constituent of the secretion of the gastric glands is pepsin, and by it the proteids are attacked. After a certain period the food now passes into the intestine, where it receives the secretions of the intestinal glands, one of which is specially active in changing cane sugar into glucose and fructose. Moreover, certain glands—the liver and the pancreas, connected with the intestine by ducts, pour their secretions in. In the secretion of the pancreas there is one ferment which is active in changing such starchy elements as have not been touched by the ptyalin, a second which attacks cane sugar, another

which acts on the proteids, and yet another which acts on fats. The bile, also, which is contributed by the liver, acts as an antiseptic and also emulsifies fatty matters. We see then that the food is being gradually changed throughout its course, from insoluble to soluble, from indiffusible to diffusible, and is being gradually absorbed in its altered form by minute vessels in the intestinal wall, which directly or indirectly distribute it to the protoplasmic cells, which require nourishment.

Plants have no digestive organs comparable to those of the higher animals, but places of food-making and of food-storage must be places where digestion is particularly vigorous.

In plants, just as in animals, many foods have to be digested before they can enter into the cell, so we can distinguish here also extra- and intra-cellular digestion, but though the details of the processes may vary they are essentially the same, and produce essentially the same result. There is a similar breaking up of the food material by hydrolysis or otherwise, and a similar use of enzymes formed by the plant. We have, for example, enzymes which act on the carbohydrates such as diastase, trehalase, maltase, enzymes such as lipase which break up fats into their constituents, fatty acids and glycerine, and also peptic and tryptic enzymes which act on the proteins.

The last question we shall touch on in connection with food is the manufacture of organic compounds. The plant world is unique in that the green plant not only manufactures its own organic compounds, but does

so also for all the world. It manufactures most of its own carbohydrates, using carbon-dioxide and water in the process, and this process is known as *photosynthesis*. This process of photosynthesis may be considered briefly and conveniently under four headings: (1) the raw materials, (2) the laboratories, (3) the energy, and (4) the products and the process.

The raw materials needed have already been mentioned—carbon-dioxide and water. Carbon-dioxide exists everywhere in the air in the ratio of about three parts in ten thousand. In the neighbourhood of towns and where there is a marked decomposition of rocks or decay of vegetable matter the percentage may be temporarily higher. It is also present in the water of ponds, lakes, and slow-running streams in a higher ratio; it may be up to one hundred times as much as in the air.

In all plants with no cuticle on the surface the carbon-dioxide enters all over the surface, but for the majority of land plants the supply must pass through special openings, the stomata, and these openings are sufficient to admit as much as five or six times the amount required.

Water, the other raw material required, is never lacking where plants are active. Its source in the majority of land plants is the soil water that enters through the roots; only in the case of the mosses, liverworts, and a few epiphytes does it enter freely into the aerial parts.

The laboratories in which photosynthesis proceeds are the chloroplasts. These are organs of various form and

size, found only in the superficial parenchyma cells of stem and foliage. The chloroplasts are embedded within the cytoplasm, just inside the outer layer, and are coloured green. Their form is subject to change due to internal causes, and they are often distorted, showing that they are soft and plastic. The body of the chloroplast seems to be like the cytoplasm, but coloured with green matter. In fact the exact relation of colouring matter to the body of the chloroplast is only a matter of conjecture. There are various varieties of colouring matter, the chief of which is chlorophyllin.

While the chemical composition of chlorophyllin is unknown, its chief physical feature is of great importance. This feature is its capacity to absorb radiant energy. The chlorophyll is so constituted that it can absorb light-waves of a certain length, and it is from these absorbed light-waves that the energy is obtained that drives the machinery of photosynthesis. If a plant be kept in the dark no carbohydrates are formed; further, it is only the chloroplast that is directly illuminated that receives this energy. Now although a leaf may absorb 40 to 70 per cent. of the sunlight and 95 per cent. of diffuse light, it is only able to store up in the carbohydrates as potential energy about ½ to 3 per cent.

The first products of photosynthesis are not exactly known, but the later product of the synthesis which is best known is starch. Now the fact that no starch can be detected in a leaf under certain conditions is no test that photosynthesis has not taken place, but only that it has taken place at a rate just rapid enough to supply

all the immediate requirements. In any event, starch is a secondary product, and represents the surplus in the manufacture of primary carbohydrates over immediate use.

The process of photosynthesis is not exactly known, but it is probable that the carbon-dioxide and water form a kind of carbonic acid which is reduced by some means, at first perhaps into formic acid, and this is then reduced to formaldehyde. Then occur a series of changes which, for the present, are unknown, and result finally in the formation of starch.

But these changes which result in the formation of carbohydrates may be considered as the first stages in the manufacture of proteins. As protoplasm is a proteid, and as it is the protoplasm that grows, wastes, and needs repair, the proteins must be considered indispensable for the welfare of the plant. Now proteins cannot be manufactured out of carbohydrates alone, so other materials are necessary, and these are found in the nitrates, sulphates and phosphates. Thus a plant, given these latter, can from them and the carbohydrates manufacture anywhere in its structure these necessary proteins, the real food of the plant. We must confess, however, that the steps in the formation of proteins are all uncertain, and so it would profit little to attempt to describe them.

CHAPTER X

REPRODUCTION

THERE are two distinct phases in the life of every organism which we may name the individual and the reproductive: the first, during which the whole energy of the organism is devoted to its own advantage, the second, in which organs come into play whose activity causes a great drain on the resources of the organism, as they are unable to provide for themselves. Moreover the offspring among the higher forms are, for a varying period, dependent on the parent for nourishment. Thus we see that nature is apt to be careless of the individual life in her endeavours to be careful of the species.

At some period in the life-history of every plant and animal, provision is made for the continuance of the species, and this may be made in one or occasionally in both of two ways: either by the separation of some part of the body which can develop directly into a new organism of the same kind, or by the separation of a cell—the ovum or egg-cell—which in itself is incapable of further development, save in exceptional cases, without previous fusion with another cell—the sperm cell—which is usually in animals, and very frequently in plants, derived from another individual.

Among the lower forms of living organisms, growth is regularly followed by fission or by budding, but as

the higher, uni-cellular organisms are reached, there is a gradual foreshadowing of organs ; and multiplication is accompanied by a series of changes which are not quite clearly understood. We have, for example, in Amœba, a mere fission, or, as in the Yeast plant, a type of budding, but in Paramœcium there is conjugation and an exchange of nuclear material. Among the primitive forms, it is worth noting that the conjugants are frequently derived from the same parents. This is exhibited in a marked degree in the sexual reproduction of Eurotium and Ulothrix, and another example of this self-fertilisation is seen in Vaucheria. From this indistinct differentiation of the sexual elements we pass to such forms as Mucor and Vorticella, where there is a conjugation of cells which are never derived from the same organisms.

In examining the lower forms of living organisms we see a growing tendency towards amphimixis, or the sexual mode of reproduction, and we may conclude that this sexual mode is important, when we consider the marvellous means taken to bring it about, and the final disappearance of all other modes in the higher plants and animals.

But even after the sexual method has been adopted, there is often a continuation of the asexual which may indeed be the chief method of reproduction, as is well shown by such forms as Hydra among animals, and the leek, the shallot, the daffodil, and the potato among plants which are propagated by bulbs and tubers respectively. Again, we may have a curious alternation of the two methods, as, for example, in Obelia, where the

sedentary, fixed, or hydroid parent gives rise by budding to a form which is free-swimming or pelagic. This latter form gives rise either to male or to female reproductive elements, which after fertilisation develop into larval forms which swim to the bottom, and becoming fixed, develop into the hydroid form from which we started. Thus in the life history of this organism we find an alternation of the asexual and sexual methods of reproduction, an alternation of two distinct types; this is an alternation of generations which may be defined as the alternate occurrence in one life-cycle of two or more different forms differently produced. In the fern we find a somewhat similar alternation of generations, but in this case the male and female reproductive elements are derived from different sources.

Among the higher plants there are many interesting devices to escape self-fertilisation, and to profit by cross-fertilisation. Among the phanerogams we find many plants bearing flowers with male and female organs which are mature at the same time, and so many are no doubt self-fertilised. But this self-fertilisation is by no means the rule, for we find that the anthers and the stigma are not usually ripe at the same time, or it may be that the position of the two sets of organs prevents this self-fertilisation. Another method adopted is that the plant bears two distinct kinds of flowers, and these are not mature at one and the same time; and still one other method exists which completely prevents self-fertilisation, namely that in which one kind of flower, the male or the female, is found. Moreover the numerous ingenious devices among plants which pre-

vent self-fertilisation and help cross-fertilisation are so numerous that there can be no reasonable doubt that nature abhors perpetual self-fertilisation.

In the animal kingdom the occurrence of hermaphrodite forms, forms in which both male and female reproductive organs are found, is much more restricted than among plants. Further, such hermaphroditic forms are seldom self-fertilising, except in the case of parasitic forms where cross-fertilisation is next to impossible. Thus we see that the demand for cross-fertilisation becomes more emphatic the higher we ascend in the animal kingdom. Low down in the animal scale sexual differentiation arises, and parthenogenesis tends to disappear, and in like manner gemmation or budding dies out. Reproduction, then, among animals soon narrows down to the sexual method; this is to the liberation of special cells from different individuals, the fusion of these cells, and the development from the product of the fusion of a larva or embryo, which gradually develops into a sexual individual generally resembling one or other of the parents.

Among animals there must be therefore an early differentiation of body or somatic cells and reproductive or germinal cells. The latter are contained in special organs until such time as sexual maturity awakens them to activity, when they undergo certain changes which are an essential preliminary to fertilisation.

In plants the germinal cells do not differ much from the somatic, and they appear only when reproduction is to take place, and though passing through a preparation for fertilisation practically identical with that of

the animal cells, they almost immediately after fertilisation lose their reproductive quality and again become vegetative.

Among animals and plants we have seen that the reproductive cells pass through a process of preparation for fertilisation in which the stages are almost identical. The main feature of this process is a reduction of the amount of chromosome material in the nucleus, and is known as the process of chromatin-reduction or maturation. This is brought about by a complex series of changes in the chromatin, always accompanied by karyokinetic division. A full account of this process would be very interesting, as it lies at the root of several important questions, but space forbids even a superficial account.

CHAPTER XI

ONTOGENY

Every living organism begins life as a single cell, and ultimately reaches a more or less varying degree of complexity according to the race to which it belongs. The study of the stages between these two extremes is known as Ontogeny; this is, the various transformations that each organism must pass through before it reaches its full complexity. The early stages in the development of an organism up to the point at which its specific characteristics begin to be well defined is known as Embryology.

If the embryo becomes self-sustaining and independent

before it has assumed the characteristic features of its parents, then this type of embryo becomes known as a *larva*.

During the seventeenth and eighteenth centuries practically all embryology was dominated by the preformationist creed. According to this view, development was simply the unfolding of a preformed miniature, which only required nourishment for its growth to the adult state. No part in the organism was formed before another, all of them were created simultaneously. Moreover, successive generations were explained by supposing that the germ contained not only a preformation of the organism into which it grew, but numerous other preformed miniatures in ever-increasing minuteness, so that at the creation the germs of over two hundred thousand millions of men were created and "packed away in the ovary of our mother Eve."

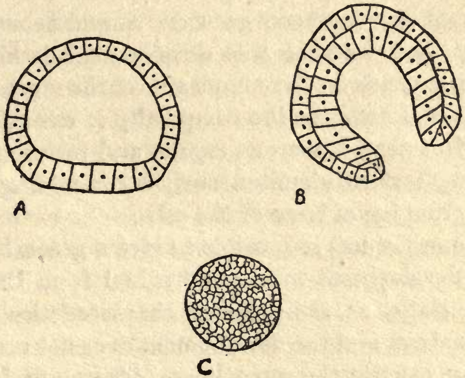
Gradually, through the labours of Wolff, von Baer, and numerous other workers, the foundations of modern embryology were laid, and proof brought forward to show that both the ovum and the spermatozoon were cells, and were both necessary in fertilisation. Baffling as the problem of fertilisation appeared, great advances have been made towards a proper understanding of it, and we know now that it is the orderly and intimate union of a sperm-nucleus of paternal origin with an ovum-nucleus of maternal origin, and the result thereof a cell with a nucleus we may call the segmentation-nucleus. At the same time a clear understanding of the processes that lead up to the fertilisation stage in the egg and sperm was obtained.

Fertilisation, which may be effected in various ways according to the habitat of the organism, is followed by segmentation. On the quantity and arrangement of the yolk in the egg the character of the segmentation depends. When the yolk is present in small amounts the whole egg divides into equal parts, as is seen in sponge, earthworm and star-fish. When there is a considerable quantity of yolk and it has collected at one part, the division is complete but unequal, as we see in the frog's egg. When the yolk is accumulated in the centre there is a superficial division, and when present in large quantity the division is confined to a small but rapidly extending area of living matter which rests on the surface of the yolk.

The final result of some of the types of segmentation is a ball of cells which may be hollow, and is known as a *blastula*, or solid, and is known as a *morula*. It may, however, be modified in various ways by the presence of a large quantity of yolk.

The hollow ball of cells almost always becomes invaginated; this is, the lower pole of the egg is pushed up until the cells come into contact with the inner surface of the cells at the other pole. The result of this invagination is the formation of a two-layered sac of cells which is named the *gastrula;* its outer layer of cells is known as the epiblast, its inner as the hypoblast, and the cavity as the archenteron, which becomes the digestive part of the food canal in the adult. From the outer layer, the epiblast or ectoderm, are formed in the adult the outer skin, the nervous system, and the most important parts of the sense-organs; while from the

inner, the hypoblast or endoderm, the lining of the most important parts of the food canal and its outgrowths is formed. In all animals above sponges and cœlenterates a middle layer appears which is called the mesoblast or



A. Section of Blastula. *B*. Section of Gastrula. *C*. Monila.

mesoderm, and it gives rise in the adult to such structure as muscles, skeleton, and connective tissue, gonads, &c.

Now in those eggs in which the segmentation is only partial, the segmentation is limited to a small superficial area lying on the yolk, and this area is called the blastoderm. When the blastoderm has reached a certain stage, a modified form of blastula is formed by a differentiation into superficial and deeper layers, and gastrulation takes place not by a simple invagination, but by a combination of folding and invagination. Yet the final result of all the types is essentially the same, giving rise alike to a three-layered embryo.

In the higher animals this formation of a three-

layered embryo is complicated by the fact that the ovum has to prepare for its future nutrition, and at the same time arrange for its freedom from external influence by surrounding itself with smooth membranes within which it may develop.

Internal development goes on simultaneously with external, and whether this development is simple or complex depends on the complexity of the organism into which it will grow, as the complexity is essentially due to the fact that numerous organs and series of organs are being formed simultaneously by a folding, fusing, or new grouping of some of the cells.

It is more or less impossible to give a general account of the development of the individual from the three-layered stage, as the peculiar characteristics of each begin to show, and the development does not necessarily follow on exactly the same lines. There are, however, some generalisations in connection with Ontogeny of which a brief account may be useful.

From the frequency of the two-layered or gastrula stage in the development of animals, Haeckel came to the conclusion that the first stable form of a many-celled animal must have been something like a gastrula. He named this hypothetical ancestor a Gastræa; and this supposition seems to be supported to a certain extent, when we find that some of the simplest many-celled animals are little more than a gastrula, *e.g.* such forms as Dicyema, Rhopalura, Salinella, and many of the simplest forms of sponges.

When we examine the whole animal kingdom, we find that the simplest animals are single-celled, and the next

stage in complexity is an aggregate of cells usually in the form of hollow balls, and then comes a series of animals closely resembling the two-layered stage in the embryo. These are in exact correspondence with the first three stages in the development of any individual organism. From these facts von Baer and Meckel and several others were led to examine the whole development of an individual, and they came to the conclusion that there was a tendency for the individual to recapitulate certain stages in the history of the race. Haeckel, a strong supporter of this view, called it the Recapitulation Doctrine or the Biogenetic Law.

Considerable importance has been placed on this doctrine, and in the popular mind it has been twisted to mean very many impossible things. All workers in Biology are agreed that there is no completeness of recapitulation, that there is only a tendency to reproduce in the individual life-history certain stages in the life-history of the race, and so the law may be stated as follows, that *ontogeny tends to recapitulate phylogeny*.

An example or two of this tendency must suffice. The heart in the higher animals, in development, is first noted as a simple straight tube similar to that of many invertebrates, then it becomes separated into an anterior portion or ventricle, and a posterior or auricular portion, resembling at this stage the heart of some of the fishes. Later the posterior portion becomes separated into two, and this corresponds in the main to the heart of some amphibians. Much later it develops by bending and fusion into a four-chambered organ in which the portion that was originally posterior now becomes anterior, and

so it forms a heart exactly the same as that of the higher types.

A second example of a slightly different kind is seen in the development of Penæus. From the egg a simple form called a Nauplius is produced, and this is simpler than any known crustacean. This grows and moults and gives rise to a second form which is called a Zoea, grows and moults again and the Zoea becomes a Mysis, which in its turn grows and moults and finally forms an adult Penæus. Now this life-history of Penæus is practically unintelligible, unless we believe that Penæus does to a certain extent recapitulate the stages in the history of the race to which it belongs.

There is a third generalisation which is also important, namely the germ-layer theory. We saw that the egg of most forms gave rise ultimately to a form in which there were three distinct layers. For a long time it was held that organs which were similar from the anatomical standpoint must have had their origin in similar layers; this is, that homologous organs were also homodermic organs. But many facts have arisen which tend to shake this belief, and it is recognised more and more that this germ-layer theory is not only inadequate but misleading, and that the primary layers of the gastrula are not strictly homologous throughout the animal kingdom.

CHAPTER XII

THE ADAPTATION OF ORGANISMS TO THEIR ENVIRONMENT

Every living organism has a definite relation to the world in which it lives, and in this chapter we must consider how the organisms make the most of their surroundings, using such features as are favourable, and protecting them from such as are dangerous either to themselves or their offspring; in other words, how the organism adapts itself to its surroundings.

It is fairly manifest that the plant, especially the higher forms, will show more adaptability than the animal, simply because the majority of plants "can't run away." They must therefore adapt themselves either temporarily or permanently to their surroundings or they must cease to exist.

What are the principal external influences that affect a living organism? They are mainly mechanical, chemical, physical, and vital.

Under the first of these, which we have termed mechanical influences, may be placed amount of space, pressure and tension; then under chemical influences we have such influences as food, air, water, and the medium in which the organism lives; thirdly, heat, light, electricity, &c. may be grouped together as physical; and lastly there are the vital influences, the

influences exerted by their neighbours, either blood-relations or not, and finally that most potent of all vital agents, man. We may, therefore, look at the organism as a minute living unit surrounded, as it were, by an infinitely large barrel, whose staves are formed of these influences, mechanical, chemical, physical, and vital, arranged in an infinitely complex manner. These influences may be looked upon as either helping or hindering the organism in its healthy development. It must be remembered, however, that these influences seldom act singly, but always in some combination, influencing the organism, it is true, but also interacting among themselves and modifying each other in such a way that the final result may be quite the opposite of what was expected.

We may now quote a few examples to illustrate the chief effects of environment. It is quite impossible in the space at our disposal to give anything like an adequate idea of the various adaptations that exist, or to recount in any way the numerous experiments that have been carried out in this branch of Biology.

It has been found by experiment that, when certain animals are kept and bred in a confined space, the offspring tend to diminish in size and ultimately a dwarf race is produced. That this curtailment of space is an important feature in nature itself, is proved by the fact that rabbits, which were introduced into Porto Santo in the fifteenth century, are now represented by a dwarf race. An interesting point in connection with these experiments is that these dwarfed forms are incapable of interbreeding with normal forms of the same species,

and this is true in the case of the rabbits quoted above. Numerous experiments have been carried on with reference to changes in the pressure of the environment, and all have shown that pressure has a marked effect on the organisms; for example, embryos have been known to broaden out under artificial pressure, and it is an undoubted fact that water currents mould shells and corals, and even water-leaves.

Coming next to chemical influences, it is a well-known fact that young animals of many kinds develop more rapidly when well supplied with oxygen than they do under normal circumstances. Further, it has been proved experimentally that a deficiency of oxygen tends to make life more sluggish, while an abundance tends to increase the agility of the organism and the rapidity of the life-processes. Nature herself proves this daily by placing before our eyes the marvellous activity of bird and insect, of air-inhabiting forms. The presence or absence of water may cause considerable modification. In plants excess of moisture is usually accompanied by the absence of strengthening tissue, while lack of water and consequently dryness of air results in the formation of a thick external cuticle and an abundance of skeletal tissue, while the entire absence of water induces encystment in many of the lower forms. An interesting example of the effect of water or its absence is seen in the gorse. Young gorse seedlings have quite normal branches and typical leguminous leaves. If these be cultivated in a moist atmosphere, they develop into adults without any of the features which we consider typical of the ordinary gorse plant.

If, however, the environment approaches the normal, the development of leaves stops, and the familiar spiny shoots of the normal plant are formed.

Changes may also be due to the alteration of the chemical composition of the medium in which the organism lives. A striking example of this is furnished in the results of a series of experiments carried out on one of the Brine Shrimps. This shrimp, *Artemia salina*, was changed in the course of generations into an allied species, *Artemia milhausenii*, by a gradual addition of salt to the medium in which they usually live.

Many interesting experiments have been made to show the effect of chemicals on single cells, and the changes induced are important when we remember that every living organism is the product of a single cell. We find from these experiments that the form of a cell may be changed and its predominant activity may be altered.

Food also has a very marked effect on the living organism. The walls of the stomach are changed when the diet is changed in the case of the Shetland gull, and these changes may be induced in many birds experimentally. When food is abundant the organisms grow, and at the limit of growth in the lower forms asexual reproduction takes place, but when the food supply is scanty, there is a marked preponderance of the sexual method of reproduction. Many authors believe that they have proved that an abundant supply of good food tends to the production of females, while a sparser supply tends to produce males. This seems to be borne out by the fact that the plant-lice or Aphides during the

course of the summer, when food is abundant, multiply very rapidly, and that all the offspring are females, and that only when food becomes scarcer and conditions less favourable does ordinary sexual reproduction recur. Yung's classical experiments on the feeding of tadpoles are often brought forward as another proof of this. In these experiments he thought he had proved that the alteration of the food was responsible for the large increase, from about 57 per cent., which is the normal, to 92 per cent. of females, and consequently the corresponding decrease in the percentage of the males. One point unfortunately was neglected in these experiments, and this point is fatal as far as the acceptability of the results are concerned—he forgot to take into consideration the sex of the individuals that died during the course of the experiments.

Of the physical forces that affect the organism, we need only consider light and heat. A rise in temperature is usually accompanied by a rapid increase in the rate of multiplication, as Maupas has shown in his experiments on Stylonichia. A decrease in warmth has generally the reverse action; it diminishes the rate of development and often tends to produce dwarfed or larval forms, while the cold of winter does have some considerable share in the production of the winter coat of many diverse forms of animals.

Light also is important, but it is not by any means easy to give a general explanation of its influence. We know that it has considerable influence in the formation of chlorophyll, and it is just possible that it may have a direct influence on the formation of pigment in various

animals. The lack of colour pigment on the under-surface of flat-fish such as the plaice, flounder and dab, we know from Cunningham's experiments to be directly connected with the absence of the light rays. One thing is certain, that it is a determining factor in deciding the mode of reproduction in many of the Algæ. Further, the variations in light have considerable influence on the anatomy and morphology of leaves, and on the movements of many free organisms.

The fourth set of environmental factors—the direct influence of organism on organism—plant on plant, animal on animal, or plant on animal, has been demonstrated again and again in the extensive literature with such a wealth of example that it is necessary to mention here only a very few. We may quote, for example, the deformation caused in the structure of sponges by other animals living in or with them; the injurious effects of certain parasites on their hosts, and the slight modifications they induce in their host's structure; the changes in the habits and structure of the various Algæ and Fungi we find associated together in the structures we call Lichens; and the fact that the varied forms of flowers are but adaptations to the types of insects that visit them.

The most important vital force which affects the organisms, whether for good or ill, is man. His influence is easily recognised when we realise that the varied forms of domesticated plants and animals are the products of his conscious selection.

Let us glance briefly at the care of offspring, a topic connected with the subject of this chapter. This is seen

to best advantage in the animal world, though numerous examples may be cited from the vegetable. Among plants the lower the rank of the organism, the less provision is made for it, but the higher we go in the plant world, the more effective are the measures taken to insure the offspring having a chance in the struggle for existence. Among the higher plants, for example, we find that the offspring, the embryo, is usually well supplied with a store of food to tide it over its infancy. Again, as the number of the offspring produced by a plant is exceedingly large, and as it would be practically impossible for any to live if they remained in the neighbourhood of the parent, some means must be adopted to scatter the offspring over as wide an area as possible. We see the results of these endeavours in the various devices adopted by the various plants; some, for instance, have developed balloon-like attachments to the seeds, which guarantee that the wind will help in their dispersal, or it may be parachute-like arrangements of hairs which serve as floats; others adopt devices by means of which the seeds are shot out to a distance from the parent. Another series of plants surround their seeds with luscious fruit in the hope that birds and other animals will aid in their dispersal. Others develop all sorts of hooks and processes which fasten the seed to whatever moving thing comes into contact with them, and thus are assured of a wide dispersal, and consequently a better chance in life. All these devices are evidences of the struggle the plants are making to adapt themselves to their environment, and to use it to their advantage.

But it is among the animals that the care of offspring is most highly developed. This may be due to the more hazardous life they lead. We cannot say in what forms parental care first appeared, nor does our ignorance matter much, for it is latent in all. It is as well developed in the lower as in the higher types, but it is more commonly ascribed to the higher types as they come more readily under our notice. Numerous examples could be cited, all equally interesting. We might mention the case of the leech and the jelly-fish, the frog and the crocodile, the spider and the insect, but we must be content with a few examples only.

Numerous fishes build nests in which the eggs are laid, and immediately after the deposition of the eggs the male mounts guard and keep all intruders away. This type is shown in a remarkable degree by the stickleback. Other fish carry their eggs in their mouths, as in the case of Arius, or as in the case of the sea-horse, in some specialised portion of the body till they hatch out. Among amphibians, parental care is even more highly developed. The obstetric frog winds the new-laid eggs round his hind-limbs and retires into some hole where he remains looking after them, and only comes out at night-fall to look for food; a walk which some assert has its main purpose not to seek food, but to acquire sufficient moisture for the developing eggs. Even more interesting are the means adopted by some frogs, where the eggs are placed in a pouch-like depression in the skin of the back and carried there till they are able to fend for themselves. Quaintest of all is the case of the male Chilian frog, which carries the eggs and the young

in a special pouch inside the mouth, a somewhat unique position.

Among birds, the evidence that can be brought forward in support of the high standard of parental care is so extensive that no one can doubt it. The care spent on the building of the nest and on the feeding of the young are such features of daily experience that they are apt to be overlooked; but who can ever forget, once they have seen it, the care with which the bird teaches its offspring to fly, to catch food, and to avoid danger, and the eager willingness with which it is done?

Every phase of parental care among animals is but another example of the struggle made by animals to adapt themselves to their surroundings.

We must always remember that the conditions of the environment are infinitely varied throughout the world. In no two regions are the conditions absolutely identical for several consecutive seconds, and so the organism must, as it were, keep pace with the ever-changing conditions. In one region certain of the environmental factors may be emphasised, in another, others; and the predominant factor generally induces a special type of organism.

CHAPTER XIII

THE STRUGGLE FOR EXISTENCE

EVERY day forces upon our notice the fact that among living organisms there is a continual struggle, a struggle which may involve the victory or the total suppression of some form of life. This is a struggle which is waged alike in the animal and the vegetable kingdom, but may be more easily understood if we consider it mainly among the animals.

Animals do not live alone, nor do they always pursue the paths of peace. Wherever animals are found, there also is there struggle; a struggle which is older than the fights of men, often very keen and often also to the death, but which is often made of small importance by the mutual aid and sympathy that exists among animals.

If anyone doubts the reality of this struggle, let him take a brief glance at the various forms of animals. Throughout the whole there is a superabundance of weapons and of armour. From the simplest forms with their offensive threads we pass to the stings of insects, the large pincers of crabs and lobsters, the teeth of sharks, the horns and hoofs and fangs of mammals. With armour it is just the same; thus we have the shells of crabs and molluscs, the scales of fishes and of reptiles, and the hair and the feathers of mammals and birds.

The forms of the struggle are very different. Hunger

and love may be said to lie at the base of all. Food has to be found for all, and which mouth is to be fed has to be decided often by tooth and claw. Many animals are carnivorous and must feed on others, which do all they can to prevent a horrible death. In other cases the struggle may be for mates, sometimes a peaceful struggle, but often one to the bitter end. There is another kind of struggle, the struggle between an animal and its environment.

That there is a struggle between living organisms we cannot deny. Fellows strive for their share of food; between foes there is a constant attack and counter-attack; mates have to be won and many are disappointed; and over all is a changeful physical environment which, as we shall see, has no mercy. But throughout it all, ennobling it and raising it high above the petty strivings of mankind, we recognise the presence of altruism, parental love and sacrifice, mutual aid and care for others.

Before we consider these different forms of struggle, we must call attention to the enormous powers of increase possessed by organisms if considered as living under favourable conditions.

A single purslane may give rise to two million seeds, a single infusorian may be the ancestor of millions at the end of a week, and were all the eggs of every cod-fish, ten millions for each, to reach maturity the whole sea would immediately become crowded with cod-fish.

But fortunately these multiplications rarely occur, and we have to thank the struggle in nature, especially the struggle against environment, that they do not.

It has often been said that the struggle for existence between fellows with the same needs is the keenest of all, and numerous examples have been quoted in its support. But this is not necessarily so, and is frequently quite the opposite. We have seen numerous cases where this is not so, and the animals seem to have discovered various peaceful devices for preventing this life and death struggle.

Of the struggle for existence between foes little need be said. Carnivores prey on herbivores, birds prey on small mammals, and so on throughout the whole realm of animal life. But birds may feed on insects and worms, and fishes may live on small crustacea, and we must not be rash and strain the meaning of this struggle for existence.

Of the third form of struggle, the competition between rival males for the possession of the female, there are countless examples. But this is a competition in which beauty and sweetness of song are often as important as strength; we have on the one side, for example, the contest between rival songsters, on the other side the fierce combats between stags.

The struggle between organism and environment is, in our opinion, the most important of all, for nature seems absolutely careless of life. In a previous chapter we have seen some of the devices by which animals keep their foothold against storm and drought and cold. One or two examples must suffice. Droughts are many and frequent, the pools are dried up, most of the inhabitants perish. But many of the simpler organisms, and indeed a goodly number of higher forms, are warned in

time, and sinking to the bottom, round themselves off and form a protective coating in which they lie dormant till the rain comes again. It is interesting to note that the longer the period of desiccation, the longer the animals take to revive, and so it seems as if the life retreated more and more, till if desiccation last long enough it may retreat beyond recall.

In spite of the numerous devices, the odds against the organism are fearful. How many seeds find a suitable germinating place ? How many of the ten million eggs of a cod-fish reach maturity ? Changing currents and hungry mouths account for many. Yet though the average remains fairly constant, we must recognise that fate is cruel to life, and that life has been battered by the shocks of doom to shape and use.

The struggle is often spoken of as cruel, but men like Alfred Russell Wallace and Ernest Thompson Seton have protested again and again against the idea that has been expressed that the whole of creation is groaning in pain. Animals do not anticipate death, nor do those which die of cold and hunger suffer much. There is some reason for believing that violent deaths are painless and easy, for men who have been mauled by lions and tigers and have survived, have stated that there was no pain and no fear, only a pleasing numbing sensation which obliterated all else. Whether the hunted, the dying, the maimed and the starving animals suffer little actual pain, each one must settle for himself, but in so doing he must remember that the happiness and mutual helpfulness of animals must be balanced against the pain and death that exist.

CHAPTER XIV

THE PAST HISTORY OF LIVING ORGANISMS

WHEN we consider the past history of the animate world, we have before us two records, neither of which unfortunately is at all complete, but both are at least helpful. In the first we have the strange tendency of the individual during its development to reproduce certain stages in the life-history of the race; in the second, such fragments as we can gather from "the strange graveyard of the buried past—the fossil-bearing rocks."

Let us consider for a brief moment the second record—Palæontology. In the past history we recognise forms which disappeared but yesterday, but as we delve more deeply into the buried pages we find traces of giant reptiles and amphibians and strange forms of armour-bearing fish. Throughout the chapters of this record we find forms that have persisted from age to age, forms that have lived from almost the beginning even unto the present day. Other races we find that have had their little day and ceased to exist, leaving behind them no single form which we may call their descendants. Other forms have also arisen, attained a period of great prosperity, and then gradually waned away, but still they left forms behind which correspond so closely with them that we cannot but accept them as their lineal descendants. As the earth grew older, other and higher

forms arose, and so we find that the buried record shows a gradual progress from simple to more complex forms.

If this record of bygone times were complete, we should be able to draw up a genealogical tree showing all the stages from the earliest Protist to Man in their proper places, but such a perfect record must always remain a dream, and necessarily so when we take into account the nature of the rocks in which the fossils are formed, and the great changes they are liable to. Moreover the structure of many animals themselves and the medium in which they lived would often be a bar to their preservation.

Imperfect however as the record is, there are numerous marvellously complete series. For example, we can trace the gradual evolution of the horse through a series of fossil-forms that leave but few stages unpresented, and so also is it with the ancestry of the elephants. In such cases the mass of evidence proves without a doubt that there was a continuously progressive evolution.

It is true that some forms, such as the Lamp-shells, have persisted almost unchanged to the present day, but in the majority, the characters of the race have gradually changed, and though the old forms are no longer represented, their lineal descendants are still with us. One of the peculiar features of the geological record is the large number of forms that have become extinct, and it is difficult to explain why they have become so. In some cases it may have been the struggle between the various competitors, in others it may have been that

the race was not sufficiently plastic to save themselves, and this latter reason may explain why we have no longer giant reptiles and amphibians; or perhaps the evolution-momentum of some particular feature got, as it were, out of hand, and produced a character which was harmful instead of beneficial to the race. One thing is certain, that the exact reasons for the extinction of many forms will never be known.

We have given here a very brief sketch of the geological record, but still sufficient to show that, in spite of all its imperfections, and of all its puzzles, it must not be neglected by the student who would form an intelligent opinion of the history of living things.

CHAPTER XV

HEREDITY

WHAT is heredity? It is the name given to the property that is passed on from one generation to the next, a property which ensures, on the whole, the transmission of the characteristic features of an organism to its offspring. The present generation of any particular race is related to the antecedent one in virtue of this property, and will be related to the generation it begets in a similar manner; hence heredity may be defined as the organic relation between successive generations.

In the majority of cases, organisms develop from an

egg-cell with which a male-cell has united in an orderly and intimate way. This is the first great fact of heredity, that each parent contributes the same amount of nuclear material to the offspring. Another fact which is perhaps more patent, is that the offspring is very like its kind. No one denies that there is a general resemblance between the offspring and its parents, but this resemblance may descend even to minute details, and so we find, for example, that malformations which were "natural" to the parents may descend to the offspring. Then there is another series of facts showing that the offspring may reproduce characters that are not exhibited by the parent, but were shown by some of the previous ancestors. This "harking back" to the ancestral characteristics, if it be very marked, is known as *atavism* or *reversion*, and of this there may be several degrees.

Now every organism is usually slightly different from its parents, and this is so much the case, that it is not usual to have any difficulty in distinguishing it from its fellow-offspring. That this difference is natural there can be no doubt, for every organism begins life as the result of the intimate union of two units of living matter which may have had very different properties.

Theories of heredity have been formulated at all times and in all kinds of intellectual language. Of the majority of these we shall say nothing, limiting our remarks to the most recent.

With regard to this modern theory, there is much controversy as to details, but the main fact stands out clear, that there is an organic continuity of generations.

Many biologists, for example Haeckel, Brooks, and Galton, had hinted at this theory, but it remained for Weismann to give it its definite expression.

What is meant by this organic continuity ? Suppose we have a fertilised egg-cell which is endowed with certain qualities. This cell divides into two, each of which has all the characters of the original ; this division goes on repeatedly, and we may suppose that all the resultant cells are endowed with the original characteristics. But now a division of labour and other changes occur among the resultant cells, so that the majority of the cells go to form the body. These naturally must lose their general characteristics as some are specialised for one purpose, some for another ; but in the meantime there are certain cells set aside and kept apart from the specialisation, and they retain their general or embryonic characteristics. They form the future reproductive cells.

A cell derived from these will be in the same position as the cell we started with, so it will develop into the same kind of organism, and this will be repeated just so long as reproduction lasts in the race.

So far so good ; but we may ask, In how many forms has this early setting aside of the future reproductive or germ-cells been observed ? It has undoubtedly been observed in certain worms, in some crustaceans, and in some insects, and also in a number of organisms both plant and animal. It is at a late period, however, in the development of the higher organisms that these cells are set aside, and this was raised as an objection to the theory, but Weismann supplied a more general

and more radical theory which he called the "continuity of the germ-plasm." This is the theory that holds at the present day.

There are certain things that have proved a fertile source of controversy in relation to the theory of heredity, and the chief of these is the question of the transmission of acquired characteristics. Many biologists have believed that gains or losses due to the influence of nutrition and of surroundings may be transmitted from parent to offspring. Numerous cases have been cited in support of this belief, and many workers in various branches of science, for example Virchow and Eimer, have written in support of it. On the other hand we have men such as Weismann and Ray Lankester who deny the transmissibility of such characters. Others there are, not few in number, who pin their faith to a modified form of Weismann's theory.

Sufficient has been said about heredity to show that it forms an integral part of Biology, and that it must not be neglected, if Biology is to be thoroughly grasped; and nothing more is necessary, as the subject has already been ably dealt with in a previous volume in this series.

CHAPTER XVI

OLD AGE AND DEATH

It seems fitting to draw this brief account of Biology to a close with a few remarks on the subject of Old Age and Death.

We are accustomed to think of living organisms as mortal, and it is difficult to tear ourselves away from this belief. Living things, it is true, are mortal, but the germ-plasm is immortal and continuous.

Many of the uni-cellular organs whose multiplication takes place by fission escape old age and death, as the whole body of the parent is divided between the offspring. It is also said that in the conjugation of many of the uni-cellular forms there is a rejuvenescence of the protoplasm, and therefore a warding off of death. When the sexual mode of reproduction is reached, the condition of things is altered but little, for the sexual cells mingle at least part of their protoplasm during fertilisation, and the resulting cell, or fertilised ovum, forms the starting point of a new generation, and pervades the whole soma thereof, and so the germ-plasm is handed down from generation to generation.

It is undoubtedly true that the individual organism which gives rise to the germ-cell may die, but that is only the death of the cells that have grown up round the germ-plasm for the purpose of protecting and

nourishing the same. We may sum this up by saying that the individual is only a necessary incident in the life-history of the germ-cells.

The duration of life in the individual varies exceedingly, and we know nothing of the laws that determine it. Great differences exist in the longevity of different forms of organisms; some may live for a thousand years, others for a few brief days, and some again may have their life's span measured by a few brief minutes.

In spite of the fact that Old Age and Death has been a topic of absorbing interest in all ages, too little attention has been paid to the phases of senescence to give us a clear understanding of them, and thus of natural death.

Various theories have been expounded. We find natural death said to be the result of arterial sclerosis or of some other form of disease. Again, it has been defined as that cessation of life which results from the accumulation of physiological arrears. Two of the more recent theories are those of Minot and of Metchnikoff, who respectively declare that death is the result of cellular differentiation, and that it is due to the increasing activity of phagocytes.

There seems to be a grain of truth in all the three views last mentioned. The more highly differentiated and specialised the cells become, the less independent they become, and the more liable are they to fall into a semi-poisoned condition and thus form an easy prey for the phagocytes.

If natural death, then, be the outcome of old age, no

matter how that old age is brought about, we must try to discover what signs may be regarded as indications of old age, and how they contribute to the final result, death.

With increasing old age we find changes in the body that are usually called atrophy. This atrophy occurs in all the tissues and organs, and is usually accompanied by loss of the cellular tissues and increase in the fibrillar, and also by a decrease in the activity of all the parts.

In the old we may note some loss of memory, less readiness in grasping new facts and in pursuing new lines of thought. There is often also a marked tendency to remember old and far-off things, a token of the characteristic loss of the old.

If we turn to the facts that an examination of the body reveals we see everywhere this atrophy of the parts, faintly indicated in one organ, more strongly marked in another. Many parts of the skeleton are in youth cartilaginous, but in the old most of these parts are replaced by bone, and though this displacement by bone indicates an advance in structure, physiologically it is far from advantageous, as it represents a loss in elasticity. The change in the structure of the bones themselves may be regarded as an advance in structure, but again it is disadvantageous, as it marks an increase in fragility.

In the digestive organs the stomach may be small; the minute glands in the walls are usually fewer in number and consequently less efficient than in the

earlier stages. The muscular layers of the intestinal walls are thinned, and this lessens their peristaltic action. The lungs become stiffened; the walls between the air-spaces become thick and hard, and the air-capacity of the lungs becomes diminished. The heart is usually enlarged, but its power is impaired, and the pulse-rate is thereby increased. We see also that the germ-cells cease their activity in the very old, and so one of the great functions of life is blotted out entirely from the history of the individual.

The whole of the nervous system suffers, and the brain itself shows us without a doubt that after maturity is reached, the shrinkage of the brain begins, and continues steadily to the very end of life.

Physiology also shows us that the shuffling gait, the tardy response, the slow speech, the imperfect sight, and the difficult hearing, are but signs of lessened power in the muscles, of diminished control over the action of these muscles, of inferior co-ordination, and of nerve decay.

These are a very few of the features that mark old age among the higher forms, but when we consider many of the lower forms in which few, or it may be none, of the organs and structure mentioned above exist, we are at a loss to find any sign of old age, but still we are met with the fact that they also spring into being, grow old, and die.

Any theory of old age, the natural corollary of which seems to be death, must explain not only the causes of old age and death in the higher forms, but also in the

lower organisms. And whether the views of Minot or of Metchnikoff, or of numerous others be correct, time and experience alone will tell.

It is only, however, by attempting to understand death and all that it means, that we shall begin to realise what life is.

BIBLIOGRAPHY

In suggesting the following course of reading, an attempt has been made to cover most of the leading sections of Biology. It must be remembered, however, that the course of reading that will give the best results, is to follow one's personal inclination, and to use that particular section as the centre from which, or to which, all other sections lead.

Books most suitable for a beginner are marked with an asterisk.

A. Origin of Life

*Moore, B.—*The Origin and Nature of Life.* This deals with practically all the theories in an elementary manner.

Schafer.—*The Origin of Life.* In this presidential address Professor Schafer deals with the origin of life from the chemico-physical standpoint.

Bastian.—*Heterogenesis.* This gives the author's views as to the spontaneous generation of Life

B. The Cell

*Wilson, E. B.—*The Cell in Development and in Inheritance.* This is a masterly account of the structure of the cell and of the various changes that occur in it.

C. Protoplasm

*The articles on Protoplasm in the *Encyclopædia Britannica* and in *Chambers's Encyclopædia.* These articles deal with the various theories as to the structure, nature, and functions of Protoplasm.

*Bütschli.—*Protoplasm* (English translation), which deals with the same features as the first mentioned.

D. Animal Intelligence

*Lloyd Morgan, C.—*Habit and Inslinct ; Animd Life and Intelligence ;* and *Animal Behaviour.* These three books supply the best introduction to those questions which deal with the psychological aspect of animal life.

E. Evolution

*Romanes.—*Evidences of Evolution.* This gives a very lucid and interesting account, and states grounds for the belief that evolution has taken and is taking place.
*Sterne, Carus.—*Werden und Vergehen.* This is the best of all popular accounts of Evolution.
*Spencer's *Principles of Biology.* Portions of this book dealing with this subject give a marvellously lucid account of this.

F. Past History

*Wood.—*Palæontology.* This gives a good account of the various forms of past life, and forms a suitable starting-point.
Zittel.—*Handbuch der Palæontologie.* A fuller and more elaborate account.

G. Old Age and Death

*Minot.—Various articles dealing with this which have been published in American journals. These articles deal with this subject from the biological and embryological standpoints.
*Metchnikoff.—*The Prolongation of Life.* In this the subject is treated more from the pathological standpoint.

H. General

The books mentioned here should be read carefully before the student starts any of those cited under the various headings. They deal with the subject from a general point of view and form one of the best introductions to a study.

Thomson, J. Arthur.—*The Study of Animal Life ; The Science of Life ; The Bible of Nature ;* and *The Wonder of Life.*
Haeckel, E.—*Generelle Morphologie.*
Driesch, H.—*The Science and Philosophy of the Organism.*

INDEX

Printed by BALLANTYNE, HANSON & Co.
Edinburgh & London

7/13 12

THE PEOPLE'S BOOKS—(*continued*)

OPINIONS OF WEIGHT

THE NATION

"A wonderful enterprise, admirably planned, and deserving the highest success."

WESTMINSTER GAZETTE

"We have nothing but the highest praise for these little books, and no one who examines them will have anything else."

TIMES

"The undertaking bids fair to prove of real value as an educative influence. . . . The information that they give, far from being scrappy, is wonderfully complete and clearly presented, and the judiciously chosen bibliographies at the end of each volume will help their readers to pass on from these capable treatises, which are something more than introductions to a fuller study of the several subjects."

NATURE

"The People's Books represent an independent and significant venture, which we cordially hope will meet with success. In this series we are provided with dainty volumes, written by people whose lives have been devoted to the subjects which they survey."

PALL MALL GAZETTE

"A series with a great and popular future."

MEDICAL TIMES

"We can imagine nothing better than these books for the use of evening science classes or for private study . . . every volume is well worth possessing."

ACADEMY

"The series bids fair to provide a liberal education at a nominal cost to all who are fortunate enough to possess it."

OBSERVER

"They seem to be taking the world for their parish"

DAILY CHRONICLE

"One volume, an anthology of verse, is entitled *Pure Gold*. This surely would be a not improper name for the whole series."

SUNDAY TIMES

"Here are volumes which throw open all the treasures of science, philosophy, history, and literature, as they are known to scholars of the present generation, books which are planned to cover the whole range of knowledge, and summarise some particular branch in an easy and simple style that is sure to urge the reader to closer study of the subject. Was I not right in declaring that education is within everyone's reach to-day? With the 'People's Books' in hand there should be nobody of average intelligence unable to secure self-education. His library—this library—should be his all-sufficing university."

THE STAR (JOHANNESBURG)

"Probably this bold undertaking by Messrs. Jack is the first attempt to throw open all the treasures of science, philosophy, history, and literature known to scholars of the present generation. We have selected the series for special mention in our leading rather than in our review columns, because we are convinced that it is precisely what is wanted in South Africa and other British Colonies, whose peoples are profoundly interested in the new knowledge, but whose chances of obtaining accurate information on the subject are few and far between."

THE EXPOSITORY TIMES

"The most amazing of all the issues of cheap books which have astonished our day and generation."

NOTES AND QUERIES

"They are not only well 'up-to-date,' and the work of competent authors, but are clearly printed on sufficiently good paper and quite prettily bound."

MR. WILL CROOKS, M.P.

"The simple, homely language in dealing with a scientific subject is such a rarity that at first sight one took to reading without effort."